

The Personal Motion Platform

Brian Vandelllyn Park

Flogiston Corporation

462 Capehill

Webster, TX 77598

713-280-8554

The Neutral Body Posture experienced in microgravity creates a biomechanical equilibrium by enabling the internal forces within the body to find their own balance. A patented reclining chair based on this posture provides a minimal stress environment for interfacing with computer systems for extended periods. When the chair is mounted on a 3 or 6 axis motion platform, a generic motion simulator for simulated digital environments is created.

The Personal Motion Platform provides motional feedback to the occupant in synchronization with their movements inside the digital world which enhances the simulation experience. Existing HMD based simulation systems can be integrated to the turnkey system. Future developments are discussed.

We now have four years of subjective experience with the Flogiston chair. In that time we have learned that:

1. The modified Neutral Body Posture is valid in a one gravity environment by providing the optimum minimal stress posture for relaxation, concentration and focus.
2. The flexibility of the hull is a positive feature which adds to the comfort of the occupant.
3. The dynamic motion of the chair is perhaps the most stimulating feature of the chair.
4. The modular hull with various suspensions is the most versatile approach. This makes the chair adaptable to many applications.

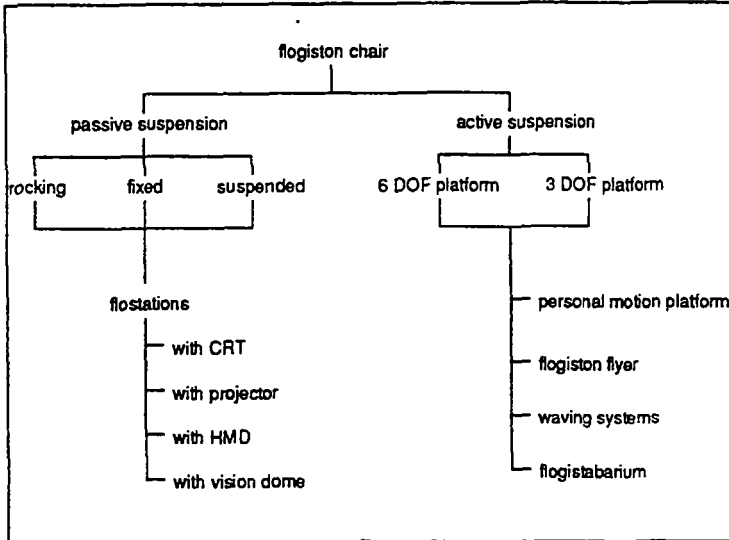


Figure 2. Flogiston chair family tree

A family of environments based on the chair is being developed. See Figure 2. For example, a flostation is a chair system that integrates the tasks of work, rest, play and learning. A flostation that uses an LCD projector is shown in Figure 3. This provides a suitable environment for multimedia learning, amongst others.

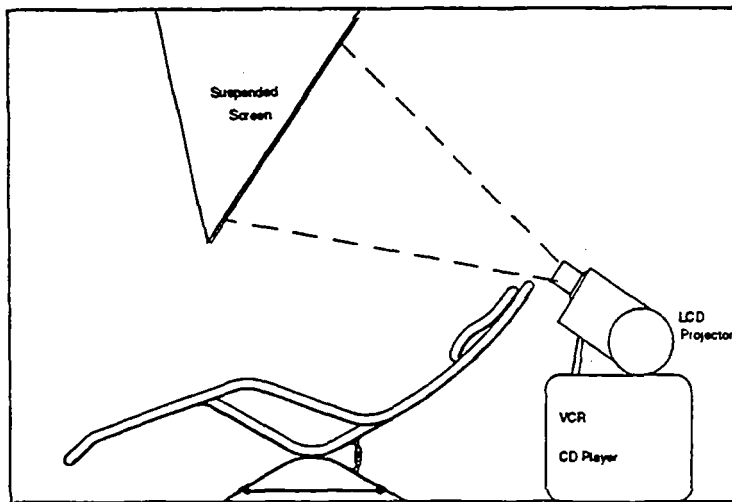


Figure 3 Example of flostation

We believe that the posture is also fundamental to the exploration of Cyberspace. Immersion in a synthetic environment requires the reduction of the awareness of the real world as much as possible to provide the illusion of being in an alternate reality. This should include the awareness of the effects of gravity on the physical body. By supporting the body in the minimal stress posture of the chair, the subjective gravity effects are reduced, and the occupant soon feels that they are floating in Cyberspace. This state is naturally conducive to micro gravity simulation.

The occupant reclines with their back at 30° to the horizontal, so that their normal perspective is also reclined. Thus the x,y, and z coordinates of the virtual world are also inclined. When the occupant moves forward in Cyberspace, the chair moves upward against gravity to enhance the feeling of movement. The orientation of Cyberspace with reference to real space can readily be adjusted in software.

In normal operation the occupant rests his hands on the chair arms so that his hands fall naturally on the motion controls. Flogiston proposes that the controls should be designed to support the hand in the neutral hand posture to minimize potential carpal tunnel effects. When the occupant wants to reach out to touch a virtual object, he raises his arms above his body in real space, to where they would normally be in zero g, which is less fatiguing than holding the arms out horizontally against gravity.

The chair is protected by a US utility patent granted in 1992. Any structure which supports the body similar to the modified neutral body posture infringes the patent.

Motion Platform

Flight simulators have used motion platforms since their early development in the 1940s. Motion enhances the realism of the experience and improves the acceptance of the simulation. Three degrees of freedom systems for pitch, roll and heave, and six degrees of freedom systems for pitch, roll, yaw, surge, sway and heave are available as standard products.

The addition of motion to VR systems is a new concept, but is as fundamental to immersion in Cyberspace as it is with flight simulators. For simulating EVA applications, the platform will simulate the dynamics of working while floating in micro gravity with a sensitivity that neutral buoyancy tank simulation is unable to reproduce, due to the viscosity of water dampening the small but significant inertia effects. For example, the reactionary forces applied to the astronaut when he contacts a structure could be fed back as motion to the platform so that he feels the experience as much as sees it. This could be as beneficial as tactile feedback.

The System

The personal motion platform combines the advantages of the modified neutral body posture with the dynamics of a motion system for an individual. Flight simulators are large, complex and expensive systems, whereas the personal motion platform is relatively simple, compact and inexpensive. By modeling the complete environment in VR, including the occupant's immediate surroundings, little external structure is needed except to support the body in the right posture and provide motion.

The system, illustrated in Figure 4, consists of a monocoque hull which supports the body in the modified neutral body posture, mounted to a small six degree of freedom motion platform. Controllers are mounted to each arm of the chair at the optimum location and orientation. Alternate hardware which can be added to the chair include a zero mass HMD support, a motion sensor stand, and a body restraint harness. The design of the hull allows fasteners to be mounted at any point on the under surface for the attachment of additional equipment.

A suitable 6 degree of freedom platform has been identified. It consists of a hydraulically servo actuated motion base assembly, servo controllers, hydraulic power supply and a digital control system. The control system consists of an Intel 80486 and two TMS320 digital signal processors. This interfaces through Ethernet to the VR processor for control. Real time motion control is performed by the control system. Multi level redundant safety mechanisms are utilized in hardware and software to ensure that the system will function safely.

An alternate gas spring/linear motor motion platform with 3 degrees of freedom (DOF) has also been identified as a candidate for a low cost system suitable for game or home use.

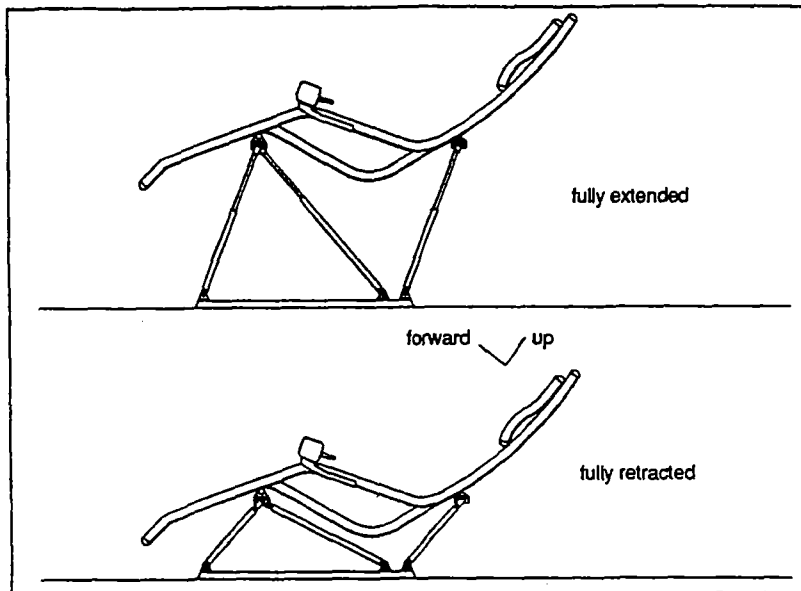


Figure 4. The personal motion platform.

The system provides:

1. Reproduction of the neutral body posture familiar to astronauts, thus increasing the fidelity of the simulation.
2. An extremely comfortable posture which enables the astronaut to remain in simulation for extended periods with minimal physical fatigue.
3. Direct feedback of accelerations in 6 degrees of freedom.
4. A complete environment for generic cyberspace immersion and control.

Operation

A block diagram of the system is shown in Figure 5.

The system operates as follows:

1. The virtual reality processor contains a math model of the synthetic environment created by the customer. The environment dynamics are computed, with resultant body axis accelerations in the six degrees of freedom. For example, accelerations can be derived from the controls on the chair, or from collision detection with virtual objects. These computed accelerations, which are results of the math model, should match what the actual environment would produce in real life.
2. The acceleration signals are passed from the virtual reality processor via Ethernet or direct connection to the PMP processor. These signals are fed into Motion Drive Laws which are basically adaptive filters that convert the accelerations to position degree of freedom commands and limit the excursion of the motion platform to prevent the pistons from ending against their stops. The Motion Drive Laws consider the frequency response of the human, the size of the motion system and the type of the vehicle. Kinematics calculations convert the degree of freedom space to leg length space. These signals are converted to analog voltages and sent to the six channel servo controller mounted on the platform base.
3. The servo controller sends the signals to the servo cylinders which provide positional feedback to correct the position. The self contained hydraulic power supply provides the power to cylinders. This results in motion of the Flogiston chair.

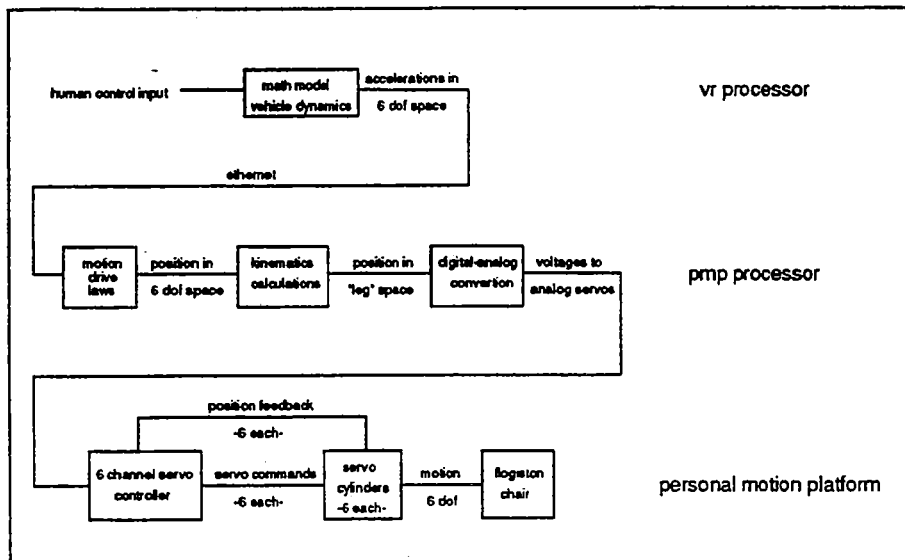


Figure 5. System block diagram.

Performance

See Table 1 below:

	Excursion (minimums)	Maximum Velocity	Max. Acceleration	Acceleration Onset
Pitch	$\pm 18^\circ$	$\pm 20^\circ/\text{s}$	$\pm 60^\circ/\text{s}^2$	$\pm 100^\circ/\text{s}^3$
Roll	$\pm 19^\circ$	$\pm 20^\circ/\text{s}$	$\pm 60^\circ/\text{s}^2$	$\pm 100^\circ/\text{s}^3$
Yaw	$\pm 21^\circ$	$\pm 20^\circ/\text{s}$	$\pm 60^\circ/\text{s}^2$	$\pm 100^\circ/\text{s}^3$
Vertical	± 7 in	± 20 in/s	± 0.5 g	± 1 g/s
Longitudinal	± 9 in	± 20 in/s	± 0.5 g	± 1 g/s
Latitudinal	± 7 in	± 20 in/s	± 0.5 g	± 1 g/s

Table 1. PMP Performance

The velocities and accelerations quoted are for a 2000 lb. payload design. The chair plus occupant typically weigh less than 350 lbs, so that the platform will be able to respond much faster if needed. The excursions can also be changed with choice of alternate cylinder lengths.

Frequency response: 90 degrees of phase lag at 1.5 Hz.

Smoothness: Less than 0.06 g's with one actuator exercised sinusoidally.

Actuator Acceleration Instability: Less than 0.06 g for any static position.

Servo Actuator Crosstalk: Less than 10% between any two actuators.

Servo Actuator Position Drift: Less than 5% over a 6 hour period.

Applications

The personal motion platform provides the sensation of movement in virtual reality for research, biomedical studies, training, entertainment, health, and stress management. In this fashion it is a generic cyberspace motion simulator that can be applied to any application where movement can enhance the immersion experience.

For micro gravity simulations, the reclining axis, posture and low resistance movement provide a sensitive platform for simulating EVA work on Space Station Freedom, satellite servicing and retrieval, MMU simulation, and so on. The platform could also be used to simulate work inside Space Station Freedom to verify workstation layouts, serviceability of racks, workspace volumes, etc.

Additional applications for the PMP may include:

1. Research into the effects of micro gravity on the body. If the phase lag between control and response is purposely increased motion sickness could be induced, measured and in theory, reversed.
2. Preflight conditioning the astronauts to micro gravity. Programs could operate the chair cyclically to raise and lower the chair continuously and set up a wave motion that affects the inner ear for example. HMD visuals could enhance the experience.
3. Post flight reconditioning of the astronauts to a one G environment after 90 to 120 days on station. An exercise regimen while lying in the chair could accelerate response to one G.

References

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